Patent Application
Docket No: 12942RR/22171.236

EXPRESS MAIL NO. EL262829314US DATE OF DEPOSIT: December 7, 2000

This paper and fee are being deposited with the U S. Postal Service Express Mail Post Office to Addressee service under 37 CFR §1.10 on the date indicated above and is addressed to: Box Patent Application, Commissioner for Patents, Washington, D.C. 20231

Michelle Baxter
Name of person mailing paper and fee

Michelle Baxter
Signature of person mailing paper and fee

# METHOD AND APPARATUS FOR SCHEDULING FORWARD LINK DATA TRANSMISSIONS IN CDMA/HDR NETWORKS


Inventor: Farid Khafizov
1700 Copper Creek Drive
Plano, Texas

Geng Wu
3401 Spring Mount Drive
Plano, Texas

David Paranchych
233 Woodcrest Drive
Richardson, Texas

Assignee: Nortel Networks Limited
World Trade Center of Montreal
380 St. Antoine Street West, 8th floor
Montreal, Quebec H2Y 3Y4
Canada

HAYNES AND BOONE, L.L.P.
901 Main Street, Suite 3100
Dallas, Texas 75202-3789
(214) 651-5927

Patent Application
Docket No: 12942RR/22171.236

# METHOD AND APPARATUS FOR SCHEDULING FORWARD DATA LINK TRANSMISSIONS IN CDMA/HDR NETWORKS

## I. Technical Field

This application relates generally to communication systems and, more particularly, to a method and apparatus for scheduling data transmissions in communication networks.

## II. Background

Referring to Figs. 1, 2a, 2b, and 3, an illustrative embodiment of a conventional code division multiple access/high data rate (CDMA/HDR) communication network 10 may include a packet data service node (PDSN) 12 that is operably coupled to the Internet 14 and a base station controller (BSC) 16 that is operably coupled to access points (APs)18a, 18b, and 18c. Access terminals (ATs) 20a, 20b, and 20c in turn may be operably coupled to one or more of the APs 18a, 18b, and 18c.

As will be recognized by persons having ordinary skill in the art, a CDMA/HDR communication network typically utilizes a combination of time division multiple access (TDMA) and CDMA. In an illustrative embodiment, each communication channel is shared among several users, but on an as-needed basis rather than a fixed time slot as in TDMA. An example of a CDMA/HDR communications network is the wireless communication network available from Qualcomm, Inc. that, in an illustrative embodiment, provides a 2.4 Mbps data rate in a standard 1.25 MHZ CDMA bandwidth.

During operation of the network 10, in an illustrative embodiment, an active set 22 of APs may communicate with the AT 20a utilizing a wireless forward communication link 24 and a wireless reverse communication link 26. In an illustrative embodiment, at any given time period, only one of the APs in the active set 22 may communicate with the AT 20a in the forward communication link 24. By contrast, in the reverse communication

link 26, the AT 20a may communicate with one or more of the APs in the active set 22.

Furthermore, during operation of the network 10, in an illustrative embodiment, in the forward communication link 24, the APs 18 may transmit a power control signal, a pilot signal, and/or a data payload to the ATs 20 using a power control channel 24a, a pilot channel 24b, and/or a data payload channel 24c, respectively. In an illustrative embodiment, the power control signal controls the power of the signals transmitted by the corresponding AT 20. Thus, in this manner, the power level of signals transmitted by a particular AT 20 is controlled by one or more of the APs 18. In an illustrative embodiment, in the reverse communication link 26, the ATs 20 may transmit data rate control signals to the APs 18 using a data rate control channel 26a. In an illustrative embodiment, the data rate control signal controls the maximum rate of data transmitted by the corresponding AP 18 to a particular AT 20 as a function of the carrier to interference ratio (C/I) for the pilot signal transmitted by the corresponding AP to the particular AT. Thus, in this manner, the maximum rate of data transmission from a particular AP 18 to a particular AT 20 is controlled as a function of the calculated C/I for the pilot signal that was transmitted from the particular AP 18 to the particular AT 20.

In a typical CDMA/HDR network, as illustrated in Fig. 3, the AP 18a may service a plurality of ATs, 20a and 20b. Conventional methods of scheduling the transmission of data from the AP 18a to the ATs, 20a and 20b, utilize a proportional fairness criteria in which a proportional fairness index is calculated for each forward communication link between the AP and the ATs. The proportional fairness index is typically calculated by dividing the peak data transmission rate by the historical average data transmission rate for some predetermined time period for each of the forward communication links between the AP 18a and the ATs, 20a and 20b. The peak data transmission rate is typically equated to the maximum data transmission rate value

generated by the ATs, 20a and 20b, as a function of the calculated C/I for the forward communications link and transmitted by the ATs to the AP 18a using the data rate control signal. The AP 18a may then transmit data to the ATs, 20a and 20b, based upon the proportional fairness index values calculated for each forward communication link. Typically, the AP 18a may then schedule transmission of data within an available time slot to the AT having the highest proportional fairness index.

The scheduling of data transmission provided by using the proportional fairness criteria suffers from a number of drawbacks. For example, the proportional fairness criteria does not work very well when not enough data is in the queue to fully utilize the available physical packet layer size. This could happen, for example, when there is a low data transmission rate at the traffic origination point or a bottleneck in the network, or where the data being transmitted is the remaining small amount of a data burst.

The present invention is directed to improving the scheduling of data transmissions in the forward communication links in CDMA/HDR communication networks.

**III. Summary**

According to one aspect of the present invention, a method of scheduling the transmission of data from an access point to a plurality of access terminals serviced by the access point using the corresponding forward communication links between the access point and the access terminals in a CDMA/HDR communications network is provided that includes the access point calculating a scheduling parameter for each of the forward communication links and access terminals as a function of a plurality of operating parameters, and the access point scheduling data for transmission to the access terminal having the largest scheduling parameter.

According to another aspect of the present invention, a communications network is provided that includes a plurality of access terminals, and an access point operably coupled to the

access terminals by a plurality of corresponding forward communication links. The access point is adapted to: calculate a scheduling parameter for each of the forward communication links and access terminals as a function of a plurality of operating parameters, and schedule data for transmission to the access terminal having the largest scheduling parameter.

According to another aspect of the present invention, a computer program for scheduling the transmission of data from an access point to a plurality of access terminals serviced by the access point using the corresponding forward communication links between the access point and the access terminals in a CDMA/HDR communications network is provided that includes instructions for: the access point calculating a scheduling parameter for each of the forward communication links and access terminals as a function of a plurality of operating parameters, and the access point scheduling data for transmission to the access terminal having the largest scheduling parameter.

According to another aspect of the present invention, a communications network is provided that includes a plurality of access terminals, an access point operably coupled to the access terminals by a plurality of corresponding forward communication links, means for calculating a scheduling parameter for each of the forward communication links and access terminals as a function of a plurality of operating parameters, and means for scheduling data for transmission to the access terminal having the largest scheduling parameter.

The present embodiments of the invention provide a number of advantages. For example, the use of the frame utilization as a weighting factor in the calculation of the scheduling parameter P permits the scheduling parameter to reflect the degree to which the frame is utilized for each forward transmission link. In this manner, the scheduling of data transmissions between the access point and the access terminals is more efficient. Furthermore, the use of a plurality of weighting factors permits the calculation of the scheduling factor P to reflect the full

range of relevant factors that effect and influence the scheduling of data transmission. In this manner, the scheduling of data transmissions is more efficient and more flexible.

## IV. Brief Description of the Drawings

Fig. 1 is a schematic view of an illustrative embodiment of a CDMA/HDR communication network.

Fig. 2a is a schematic view of an illustrative embodiment of the communication during the forward communication link between the access points and access terminals of the network of Fig. 1.

Fig. 2b is a schematic view of an illustrative embodiment of the communication during the reverse communication link between the access points and access terminals of the network of Fig. 1.

Fig. 3 is a schematic view of an illustrative embodiment of a CDMA/HDR communication network in which an access point services a plurality of access terminals.

Fig. 4 is a flow chart illustration of an illustrative embodiment of a method of scheduling the transmission of data in the forward communication links between an access point and a plurality of access terminals in a CDMA/HDR network.

## V. Detailed Description

Referring to Fig. 4, the reference numeral 100 refers, in general to a method of scheduling the transmission of data between an access point and a plurality of access terminals in the CDMA/HDR communications network 10 in which an AP 18 servicing a plurality of ATs 20 calculates a scheduling parameter P for each of the forward links between the AP and the ATs using the following equation in step 102:

$$P_i = (R_{MAXi} / R_{AVGi}) * U_{FRAMEi} \qquad (1)$$

where $P_i$ = the scheduling parameter for the ith forward communication link for the corresponding ith AT;

$R_{MAXi}$ = the maximum data transmission rate for the ith forward communication link for the corresponding ith AT;

$R_{AVGi}$ = the average data transmission rate for the ith forward communication link for the ith corresponding ith AT for a predetermined time period; and

$U_{FRAMEi}$ = the frame utilization for the ith forward communication link for the corresponding ith AT.

In an exemplary embodiment, the maximum data transmission rate for the ith forward communication link $R_{MAXi}$ is substantially equal to the maximum data transmission rate transmitted to the AP 18 by the corresponding AT 20. In an exemplary embodiment, the frame utilization for the ith forward communication link $U_{FRAMEi}$ calculated using the following equation:

$$U_{FRAMEi} = DPA_i / PS_i \qquad (2)$$

where $DPA_i$ = the size of the data payload available to send to the ith AT; and

$PS_i$ = the physical layer packet size corresponding to $R_{MAXi}$.

The AP 18 may then schedule data for transmission to the AT 20 having the highest scheduling parameter P in step 104. The AP 18 may then transmit a data packet to the scheduled AT 20 in step 106. The AP 18 may then repeat steps 102, 104 and 106. In this manner, the scheduling parameter P is generated using a plurality of indices. Furthermore, the use of the frame utilization $U_{FRAME}$ as a weighting factor in the generation of the scheduling

parameter P ensures that the scheduling of data transmissions over the forward communication links between the AP 18 and the ATs 20 takes into account the frame utilization and thereby more efficiently schedules the transmission of data.

More generally, the scheduling parameter P may be calculated using the following equation:

$$P_i = (R_{MAXi} / R_{AVGi})* WF_1 * WF_2 * \ldots * WF_j \qquad (3)$$

where $P_i$ = the scheduling parameter for the ith forward communication link for the corresponding ith AT;

$R_{MAXi}$ = the maximum data transmission rate for the ith forward communication link for the corresponding ith AT;

$R_{AVGi}$ = the average data transmission rate for the ith forward communication link for the corresponding ith AT for a predetermined time period; and

$WF_1 \ldots WF_j$ = weighting factors to be used to generate the scheduling parameter P, where j varies from 1 to N.

In an exemplary embodiment, the weighting factors may include one or more of the following: the frame utilization $U_{FRAMEi}$, and the priority of the data to be sent using the ith forward communication link $Priority_i$. In an exemplary embodiment, all of the weighting factors $WF_j$ are expressed as a fraction that can vary from zero to one. In a further exemplary embodiment, one or more of the weight factors $WF_j$ are also normalized.

The present embodiments of the invention provide a number of advantages. For example, the use of the frame utilization as a weighting factor in the calculation of the scheduling parameter

P permits the scheduling parameter to reflect the degree to which the frame is utilized for each forward transmission link. In this manner, the scheduling of data transmissions between the access point and the access terminals is more efficient. Furthermore, the use of a plurality of weighting factors permits the calculation of the scheduling factor P to reflect to full range of relevant factors that effect and influence the scheduling of data transmission. In this manner, the scheduling of data transmissions is more efficient and more flexible.

It is understood that variations may be made in the foregoing without departing from the scope of the present invention. For example, additional weighting factors could also be used in addition to, or instead, of the weighting factors of the present disclosure in order to further refine the calculation of the scheduling parameter P. Furthermore, the calculation of the scheduling parameters and/or the actual scheduling decision may be implemented by the access point and/or other functional elements of the communications network such as, for example, the base station controller 16. Finally, the calculation of the calculation of the scheduling parameters and/or the actual scheduling decision may be implemented by one or more scheduling controllers distributed throughout the communications network.

It is understood that other modifications, changes and substitutions are intended in the foregoing disclosure and in some instances some features of the disclosure will be employed without corresponding use of other features. Accordingly, it is appropriate that the appended claims be construed broadly and in a manner consistent with the scope of the disclosure.